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# DGPS Reference Station Assembly Manual

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## Introduction

The Differential GPS (DGPS) Reference Station Interface Board connects to a Motorola Oncore VP OEM GPS receiver to create a low cost 8-channel DGPS Reference Station. The Reference Station provides pseudo-range differential GPS corrections that conform to the RTCM SC-104 Type 1 Version 2.1 message format. These can be transmitted via data link to remote users. Possible data links are radio modems, terminal node controllers (TNC), or telephone modems. Remote users receive the corrections and apply them to their DGPS ready receiver to calculate a DGPS solution.

For example, a Radio Amateur installation would use a 2-meter transmitter and TNC. Using the 2-meter frequency of 144.39 MHz (the new APRS frequency) APRS trackers can take advantage of DGPS accuracy. No special equipment is needed by remote users. Corrections are received using a 2-meter (mobile or handheld) receiver and TNC. The output of the TNC is connected to a DGPS "ready" receiver.

Commercial users can connect the DGPS Interface board to commercial data radios. The responsibility of using the correct frequencies is up to the user.

Possible uses include:

- Search and Rescue
- Fire Fighting/Flood Area Boundaries
- Automatic Vehicle Tracking
- APRS Trackers
- Parades and Marathons
- Balloon Tracking
- Research and Development
- Anything that requires increased GPS accuracy

Setup of the DGPS Reference Station is easy. The output baud rate and the Station ID is selected via jumpers. The latitude, longitude, and altitude of the reference location and the rate at which corrections will be transmitted are programmed via software commands. The Reference Station then operates without any further intervention.

### Features

- Operates with the Motorola Oncore VP 8-Channel GPS Receiver
- Reference Station is Compatible with DGPS “ready” receivers that accept RTCM SC-104 Type 1 Version 2.1 Message
- Easy setup and operation, suitable for portable operations
- Microcontroller socketed for future upgrades/customization
- Programming via RS-232 serial port
- Outputs RTCM SC-104 Type 1 Message with a selectable RS-232 output baud rate: 1200, 2400, 4800, and 9600 baud
- LED Indicates Proper Operation
- Selectable Station ID: 0 - 1023
- Power Requirements: 7 - 30 VDC
- Power Consumption: 235 milli-amps typical with Oncore VP with Active antenna
- Lithium Battery Backup Option for Oncore VP's without battery backup

Availability and Information on this and other GPS products from TAPR, see the TAPR GPS Web Page at <http://www.tapr.org/gps>

### Acknowledgments

The DGPSIB designers, Steven Bible, N7HPR, and Doug McKinney, KC3RL, would like to thank Greg Jones, WD5IVD and TAPR for supporting this project. Also a big thanks to Tom Clark, W3IWI, Lyle Johnson, WA7GXD, and Rick Hambly, WB2TNL for their expert help and suggestions. Last but not least, thanks to the beta testers Steve Dimse, K4HG, Rich Garcia, K4GPS, Stan Huntting, KW7KW, and Jeff King, WB8WKA.

## Parts List

Check off the part in the [ ] space provided as you locate and verify it against this list.

<input type="checkbox"/>	1	DGPS Interface Board assembly
<input type="checkbox"/>	4	7/16” standoffs
<input type="checkbox"/>	8	4-40 1/4” screws
<input type="checkbox"/>	4	Paper washers
<input type="checkbox"/>	1	9-pin DE9P male connector
<input type="checkbox"/>	1	9-pin DE9S female connector
<input type="checkbox"/>	1	4” Ribbon wire, 4 conductor
<input type="checkbox"/>	1	4” Ribbon wire, 2 conductor
<input type="checkbox"/>	1	4” Twisted Pair Wire
<input type="checkbox"/>	1	Assembly/Operation Manual (This Document)

# **Construction Notes**

## **Electrostatic Protection**

The DGPSIB has been shipped to you in an anti-static bag. Observe anti-static precautions when assembling the Reference Station.

You are now ready to begin construction of the DGPS Interface Board. It is recommended that when assembling the DGPSIB, that you use a very fine pointed soldering tip on an iron of relatively low wattage (25 watts maximum, 15 watts is ideal). Due to the proximity of some of the traces on the PC board, solder bridges are a very distinct possibility. A low wattage soldering iron, fine pointed tip, clean rosin core solder (small size) is the order of the day. Following these points could eliminate several hours of troubleshooting (or worse). This is good practice when working on any kit.

In addition to the soldering iron and solder, you will need small flush or semi-flush cutting pliers and small-tipped long nosed pliers.

Pay careful attention to the directions that follow. Keep the tip of your soldering iron bright and clean, wiping it frequently on a wet rag or sponge. Make solder joints carefully, but swiftly. Prolonged heat on a PC board, as well as too much heat, can be disastrous and can ruin a PC board. Two to three seconds should be enough time to apply heat to any joint. Joints that have ground pad connections may require a larger wattage iron to ensure faster heating for soldering.

The DGPSIB was assembled using a process called wave soldering. All the components were placed on the board and then passed over a molten flow of solder. As a consequence, some of the holes you need to install wires into are covered with solder. This is not a problem. Simply use a solder sucker or solder wick to remove the excess solder from the holes. This will make insertion of the wires much easier. If you are unable to do this, then heat the solder pads as you insert the wires into the holes. This will allow the wire to pop through. Make sure that that you apply solder to the joint. Check that the connection has a good physical connection and it is bright and shiny.

The DGPS Interface Board (DGPSIB) is the heart of your DGPS Reference Station. You need a Motorola Oncore VP 8-Channel OEM GPS receiver to mate to the DGPSIB. At present there are no other GPS receivers compatible the DGPSIB. You will also need a suitable enclosure, power supply, GPS antenna, and data link. It is recommended that an all metal enclosure be used to minimize the amount of RFI that emanates from the Reference Station.

The DGPSIB has been assembled and tested for you. You will need to select the output baud rate and Station ID via jumpers on the DGPSIB and you need to solder the wires for power and data communications to suitable connectors. Male and female DE9 connectors are supplied as they are the most common serial connectors. Read through the entire instructions before assembling your Reference Station. This way you can formulate a plan as to how to enclose the Motorola Oncore VP and DGPSIB with power and data connectors.

Throughout these instructions it is assumed that you will be interfacing your Reference Station to a radio modem or terminal node controller (TNC). Since the output baud rate is selectable, the user can send the RTCM SC-104 corrections to any system that can accept serial RS-232 levels.

## Construction

### Power Connection (Refer to Figure 1)

Red and Black (or Red and Gray) wires are supplied with the kit for a power connection. A power connector is not supplied so that you may select one of your own. There are many to choose from. The most popular are the coaxial power connectors that you see on most products today. Choose the connector that best suits your application.

- [ ] Strip approximately 1/8" of insulation from each of the wires on both ends.
- [ ] Lightly tin the wires with solder.
- [ ] Solder the Red wire to the B+ hole in the DGPSIB. Refer to Figure 1.
- [ ] Solder the Black (or Gray) wire in the GND hole. Refer to Figure 1. Be careful not to cause a solder bridge to the nearby resistor.

At this point you want to test the power supply on the DGPSIB. This is a good time to do it as you do not want to destroy your Motorola Oncore VP.

- [ ] Connect the power leads to a suitable power supply: 7 - 30 VDC.
- [ ] Using a Voltmeter measure the voltage across the orange 330uF capacitor. The negative side is toward the Maxim MAX232 chip.
- [ ] Measure +5 VDC plus or minus 0.2 volts.
- [ ] Okay! Let's move on.

**Note:** If you do not see the correct voltage, double check everything. See that you have power applied at the correct polarity. Check that there are no solder bridges.

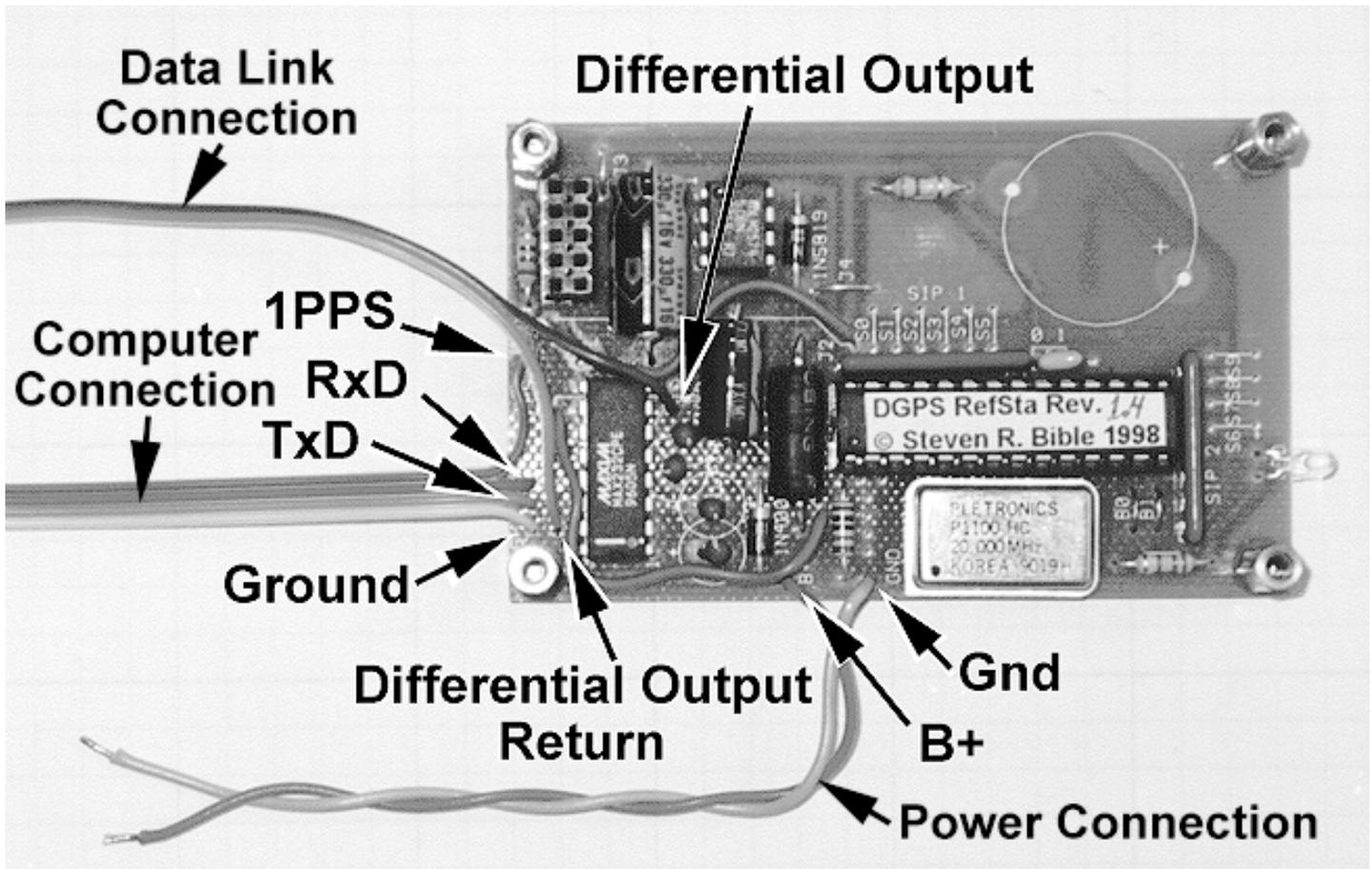


Figure 1. Location of Power and Data Connections

## Data Connections (Refer to Figure 1)

There are two RS-232 serial connections, a Computer connection to the Motorola Oncore VP and a Data Link connection from the DGPSIB. Two ribbon wires are supplied, a four and two conductor.

**Note:** When assembling DE9 connectors, heat shrink tubing can increase mechanical strength and protection from shorting.

### Computer Connection

Using the four conductor ribbon cable supplied with the kit:

- [ ] Separate the conductors approximately 1/2" from each end of the ribbon cable.
- [ ] Strip approximately 1/8" of insulation from each of the wires on both ends.
- [ ] Lightly tin the wires with solder.
- [ ] Insert one end of the cable into the Computer Connection holes labeled **G**, **T**, **R**, and **1PPS**.
- [ ] Solder all four wires to the DGPSIB.
- [ ] Check your work. There is a good physical connection, no solder bridges, and the joints are bright and shiny.
- [ ] Solder the female DE9S connector to the ribbon cable according to Table 1:

DGPSIB	DE9S Pin
G (Ground)	5
T (Transmit)	2
R (Receive)	3
1PPS	1

Table 1. Computer Connection Pin Assignments

### Data Link (Differential Output) Connection

Using the two conductor ribbon cable supplied with the kit:

- [ ] Separate the conductors approximately 1/2" from each end of the ribbon cable.

- [ ] Strip approximately 1/8" of insulation from each of the wires on both ends.
- [ ] Lightly tin the wires with solder.
- [ ] Insert one end of the cable into the Data Link Connection holes labeled **Diff** and **G** (labeled as **Differential Output** and **Differential Output Return** in Figure 1).
- [ ] Solder two wires to the DGPSIB.
- [ ] Check your work. There is a good physical connection, no solder bridges, and the joints are bright and shiny.
- [ ] Solder the male DE9P connector to the ribbon cable according to Table 2:

DGPSIB	DE9S Pin
Diff (Differential Output)	3
G (Differential Output Return)	5

Table 2: Data Link Pin Assignments

### Lithium Battery Option

This option is for Motorola Oncore VP's that **do not** have a battery backup option installed. **Do not** install a Lithium Battery on the DGPSIB if the Oncore VP you are using has the backup battery option installed.

A Lithium Battery is not included in the kit. A 3 Volt 165 mAh coin Li battery with solder tabs (DigiKey P202-ND) will do nicely. Due to the limited space, the installation will require electrically isolating the battery from the RF shield on the Oncore VP. The solder tabs may need modification to place the battery as close to the PCB as possible. Insure the "+" on the battery goes into the "+" on the PCB.

To correct the problem of the positive post being a little high, the post needs to be bent outward and then inward to make slack so that the positive and negative post are level. Also, the GPS metal can requires electrical tape to ensure no shorts (note that 820k resistor is in the negative leg, so that if any shorts do occur, the short is only 3.6 microamps).

## Setup

Setup consists of soldering jumpers on the DGPSIB to select the Differential Output Baud Rate and Station ID.

### Setting the Differential Output Baud Rate

(Refer to Figure 2)

The Differential Output Baud Rate is selected by jumpers **B0** and **B1**. Without a jumper installed, the respective bit is a Logic **High**. Soldering a jumper in place makes the respective bit a Logic **Low**. The default Baud Rate setting is 2400 baud (**B0** = HIGH and **B1** = HIGH). The Output Baud Rate may be selected to any of the baud rates listed in Table 3. The word length-parity-stop bits is 8N1.

**Note:** The most common output baud rate for RTCM data is 4800 baud (8N1).

This is a good speed to select for testing without the data link allowing the output of the Reference Station can be connected directly to a remote GPS receiver.

Baud Rate	B0	B1
1200	Low	High
2400 (default)	High	High
4800	Low	Low
9600	High	Low

Table 3. Output Baud Rate Jumper Selection

[ ] Jumpers installed for the desired Output Baud Rate. The baud rate selected is \_\_\_\_\_ (8N1).

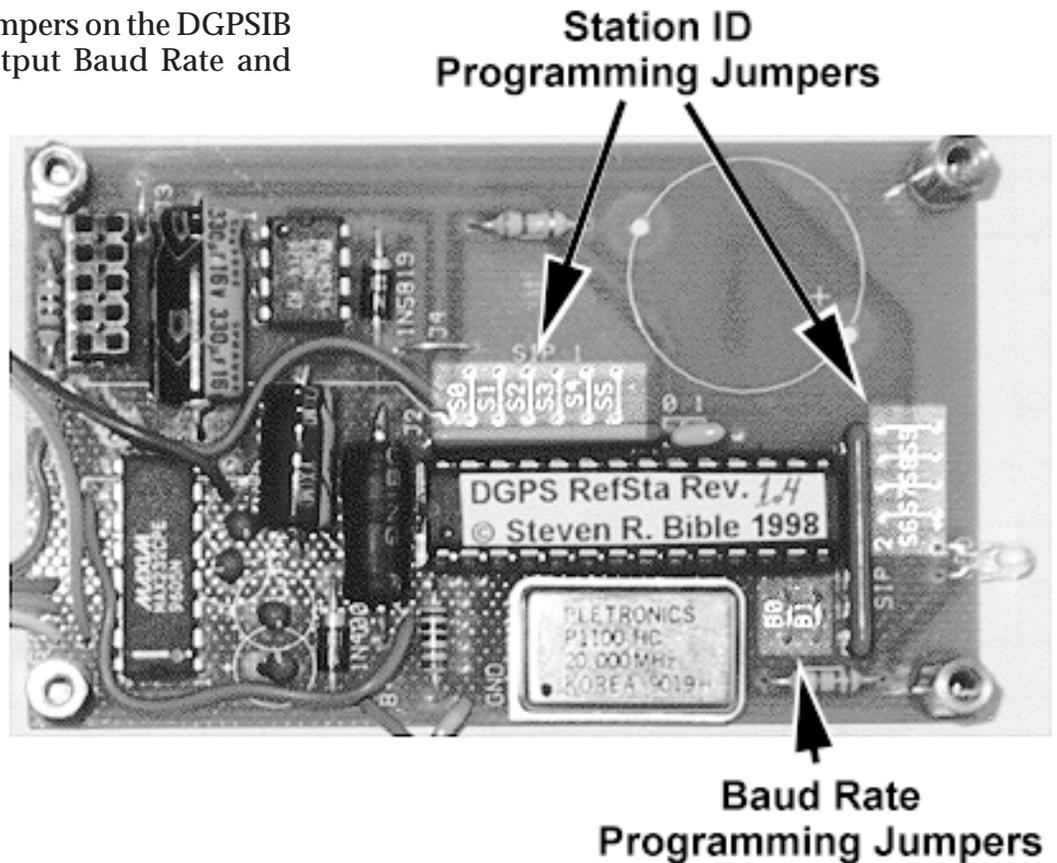


Figure 2. Location of Programming Jumpers

**Setting the Station ID** (Refer to Figure 2)

The Station ID is selected by jumpers **S0** through **S9**. Without a jumper installed, the respective bit is a Logic **High**. Soldering a jumper in place makes the respective bit a Logic **Low**. The default Station ID settling is 1023 (**S0** through **S9** = High). The Station ID may be selected to any value from 0 to 1023.

**Note:** The silkscreen labeling of **S0** through **S9** does not follow conventional binary notation. Use Table 4 to assist in determining which jumpers to install for the chosen Station ID.

First, convert your selected Station ID to a binary value. Second, mark the third row with ones and zeros that correspond with the binary value. Each zero equals a Low and requires a jumper be install in the respective **S0** through **S9** location cited by the table. For example, the Station ID of 73 equals 0001001001 binary. Jumpers need to be installed in **S0**, **S1**, **S2**, **S4**, **S5**, **S7**, and **S9**

Binary Value	2 <sup>9</sup>	2 <sup>8</sup>	2 <sup>7</sup>	2 <sup>6</sup>	2 <sup>5</sup>	2 <sup>4</sup>	2 <sup>3</sup>	2 <sup>2</sup>	2 <sup>1</sup>	2 <sup>0</sup>
Jumper	S0	S1	S2	S3	S4	S5	S6	S7	S9	S8

Table 4. Station ID Jumper Selection

**Note:** Some versions of the Motorola Oncore VP have a straight OCX connector for the antenna connection. A right angle MCX connector will be needed for the antenna connection. The Station ID jumpers S6 through S9 are directly below this connection. Since any jumpers installed will be grounded there should be no problem with them touching the MCX connector.

### Installing the Motorola Oncore VP

Remaining parts are four 7/16" standoffs, eight 4-40 \_" screws, and 4 paper washers. The Motorola Oncore VP mounts to the top of the DGPSIB. Mate the 2x5 female header of the DGPSIB with the 2x5 male header of the Oncore.

The user may choose to use a threaded standoff (see Figure 3) to mount the DGPSIB and Motorola Oncore VP assembly in an enclosure. The threaded standoff is not supplied in the kit.

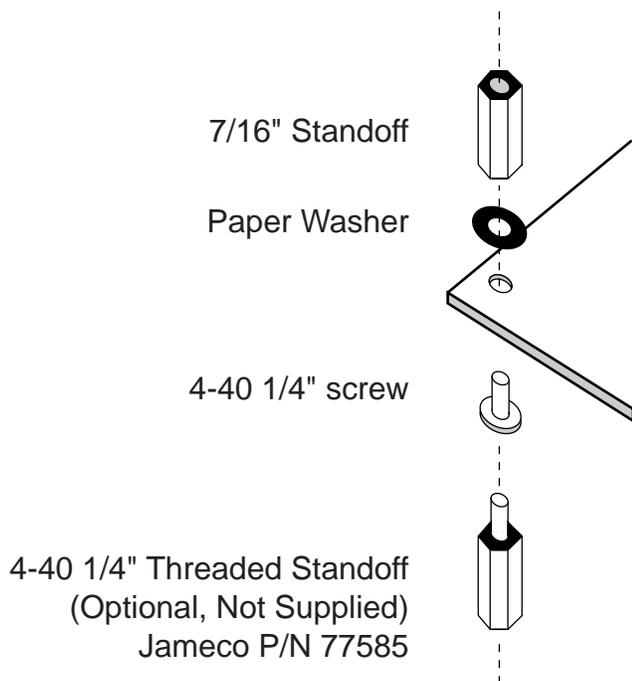


Figure 3. Mounting Hardware

**Note:** To obtain a better ground connection between the Motorola Oncore VP and the DGPSIB, carefully scrape the green solder mask around the screw holes. The screws have star lock washers which will take a bite into the foil. **Do not scrape off the copper foil!**

[ ] Install 4 standoffs to the top of the DGPSIB using a 4-40 1/4" screw and paper washer. Refer to Figure 3 for placement of the hardware. **Note:** Do not tighten the screws at this time.

[ ] Position the Motorola Oncore VP so that the 2x5 headers mate. Press the Oncore into position.

[ ] Install the remaining 4-40 1/4" screws.

**Note:** Do not tighten the screws at this time.

**Warning!** Do not warp the Oncore and DGPSIB when tightening the screws.

[ ] Snugly tighten all eight screws until hand tight.

Congratulations! Assembly of the DGPS Reference Station is complete.

[ ] Check your work, carefully inspect the assembly for any potential problems.

[ ] Everything is just great!

## Operation

Figure 4 shows the basic flow of information for the Reference Station.

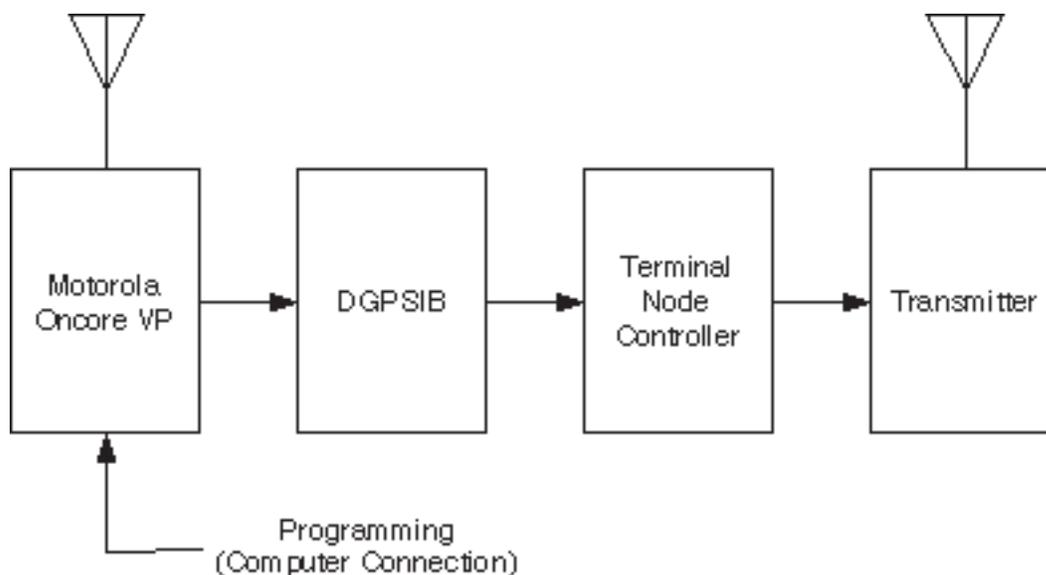


Figure 4. Basic Reference Station Block Diagram

### Overview

The Motorola Oncore VP is programmed from a PC Serial Port for DGPS operations. Presently there are two software programs to choose from to program the Oncore VP: Motorola PC Controller Utility Program (DOS) and TAC32 by CNS Systems (Windows 95/NT™). TAC32 is available from TAPR <http://www.tapr.com/gps/tac32/> or CNS Systems <http://www.cnssys.com/tac32/>. As of the date of this writing, TAC32 is in beta testing. TAC32 is a complete software package that can perform a site survey (position averaging) and set the Oncore VP for DGPS operations.

The Reference Station's antenna latitude, longitude and altitude is set in the Oncore VP. If the location is not known, a site survey can be performed. GPS positions can be averaged over several hours to gain a position. The rate at which DGPS correction data will be transmitted is also programmed into the Oncore VP.

Once the Oncore VP is programmed for DGPS operations, the corrections sent to the DGPSIB are in Motorola Binary format. These are converted to RTCM SC-104 Type 1 message format by the DGPSIB. The LED will toggle on then off for each RTCM message sent. For example, if the rate of

transmission is every 5 seconds, the LED will turn off for 5 seconds and then turn on for 5 seconds. The LED serves as a visual indication that the Reference Station is operating correctly. If the LED is not toggling on and off, recheck the programming of the Oncore VP.

The RTCM messages exit the DGPSIB from the Differential Corrections connection at the selected baud rate. This connection is at RS-232 levels and can be sent to any device capable of receiving RS-232 level serial data. To check the operation of the Reference Station, a terminal program, such as Windows 95™ HyperTerminal, set at the output baud rate can receive the DGPS corrections. The corrections data should look similar to the following:

```
Y~A@GX|jBCa|_hNOUD\S_QMigW { oxiB W f SEwGKBL@^Y@lBzq cs@sny  
fA~ ] XRgBIa|_hNouD,h^nxF@h@DEb|_pWwY@tBOEKeh aiMrBzq FL|JQX  
fA~ ] Xj@B@a|_hNouD,h^NyAkW { OJHEIhwY@tDYOEFkw acoI} EN@yKCsRn
```

In a typical Reference Station installation, the DGPS corrections are sent to a radio modem or Terminal Node Controller (TNC). The modem or TNC should be set at the output baud rate of the DGPSIB. Example settings for a TNC are given below. Once the corrections enter the modem or TNC, they are transmitted out the data link.

Remote users reverse the process above by receiving the RTCM messages with a receiver and radio modem or TNC. The output of the modem or TNC is applied to the RTCM input of a DGPS "ready" receiver. Refer to the operators manual of the GPS receiver for RTCM connections and DGPS operation.

### **Determining the Reference Station Location**

The exact latitude, longitude, and altitude of the Reference Station antenna must be known for DGPS operations. If the site has been surveyed, record this information for programming into the Oncore VP.

If the location is not known a site survey can be performed by averaging GPS positions for several hours using TAC32 software (requires Windows 95/NT™). TAC32 can perform the site survey and set the Oncore VP for DGPS operations (explained below). Follow the instructions in the help file for setting the averaging parameters and reference location.

SA Watch is another Windows 95 program that can perform a site survey. SA Watch is written by Stan Huntting, KW7KW. It is available from <http://www.sni.net/kawin/pages/sawhatis.htm>.

DOS users can perform a site survey using **Showtime**, written by Tom Clark, W3IWI. It is available from <ftp://aleph.gsfc.nasa.gov/GPS/totally.accurate.clock/distribution/>. Follow the directions in the README to install **Showtime**. Instructions to run **Showtime** are in Showtime.doc.

**Programming the Motorola Oncore VP for DGPS Operations**

TAC32 can program the Oncore VP for DGPS Operations. Refer to Figure 5.

From the GPS Mode Receiver Selections window, select

- **GPS Mode:** 0-D Nav (timing)
- **Position Fix mode:** All in view
- **Satellite Selection:** Highest in the sky
- **Iono Corrections:** Disabled
- **Elevation Mask:** 10 Degrees
- **DGPS Output:** Activate
  - Choose secs/msg for the desired message rate
  - Align Messages is optional

Click on OK

The LED on the DGPSIB should toggle on and off at the rate of secs/msg.

DOS users can program the Oncore VP using the Motorola PC Controller Utility program. Enter the following commands to enable DGPS Operations:

**Ionosphere Correction - Disable**

ion d

**Satellite Mask Angle**

mask 10 (default value)

**Satellite Select Mode - Highest-in-sky**

sm h

**Position Fix Algorithm - N-In-View**

fix n (default value)

**Correction Threshold**

corthr 0 32 (default value)

**Position-Hold Position**

php [+ or -] ll mm ss.sss [+ or -] lll mm ss.sss  
hh.hh [ 0|1] (0 = gps height and 1 = msl height)

**Position-Hold Enable**

ph e

**Output Pseudorange Correction**

corout xx (where xx equals the number of seconds per message)

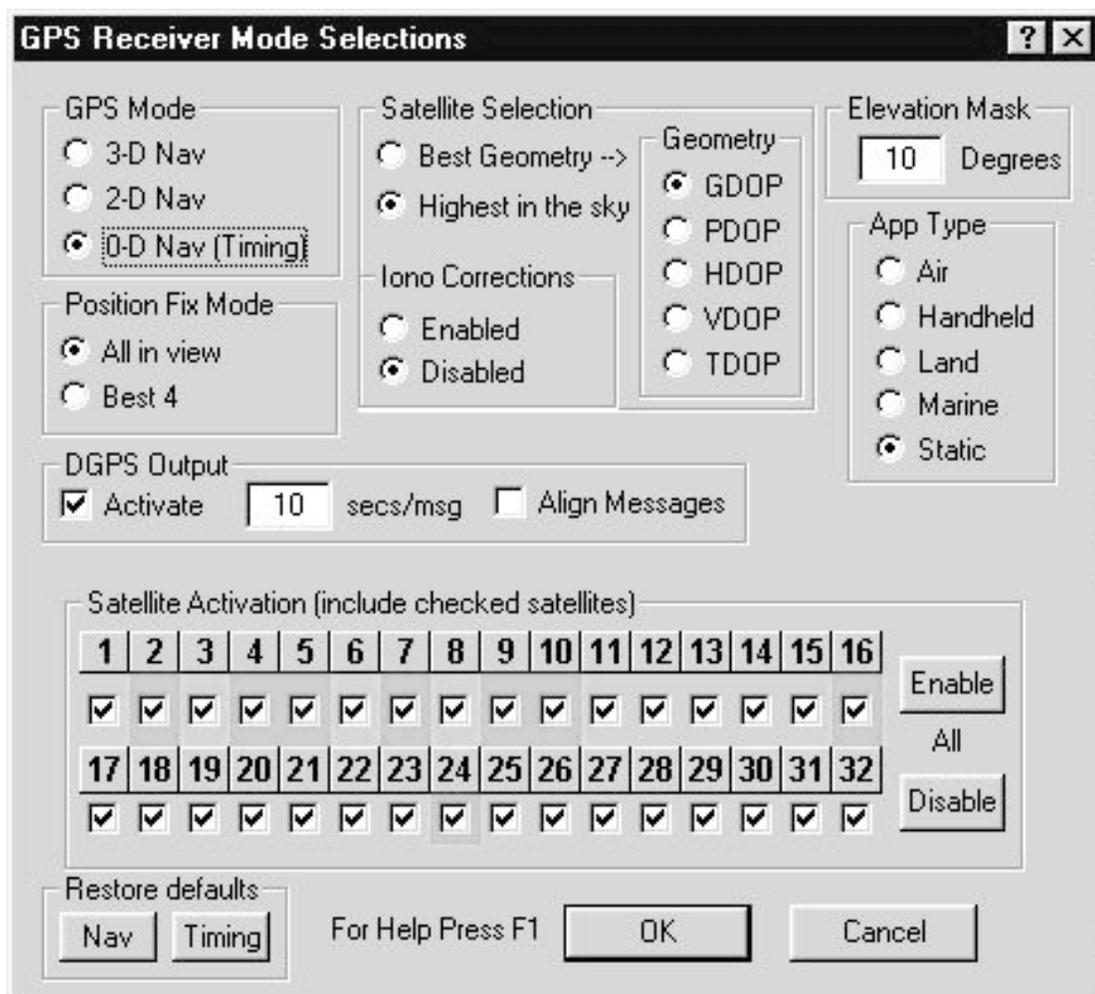


Figure 5. TAC32 GPS Mode Receiver Selections

## Interfacing to a Terminal Node Controller (TNC)

The section describes how to set up a TNC to the DGPSIB. First, you will need to initialize the TNC before connecting it to the DGPSIB.

Connect the TNC to a PC running a terminal program such as Windows 95™ HyperTerminal. Refer to the TNC Operator's Manual for an explanation of the following commands. Enter the following commands:

```
MY [ callsign]
UNPROTO DGPS
BTEXT !DDMM.MM[ N|S] /LLLMM.MMM[ E|W] DGPS
Correction provided by [ name, callsign]
BEACON E 120
PACTIME A 10
```

At this point command the TNC to enter Transparent or Converse mode. To enter Transparent enter "T". To enter Converse mode enter "CONV".

**Note:** If power is lost, the TNC will return to Command mode.. This is particularly troublesome if the Reference Station is to be used at remote sites. One solution would be to place all equipment on an Uninterruptible Power Supply. Another solution would be to connect to the TNC thus forcing it into CONV or TRANS mode depending on CONMODE command.

### Remote Users

Remote users receive the RTCM messages on the transmitted frequency using a compatible receiver and TNC. The output of the TNC is wired to the GPS receive. Refer to the Operator's Manual for the GPS receiver to determine where the data is to be applied and at what baud rate.

**Note:** During beta testing of the Reference Station, it was discovered that Garmin brand GPS receivers do not like the address information before the RTCM message. For example, the string

```
N7HPR>DGPS:Y~A@GX|jBCa|_hNOUD...
```

The address information "N7HPR>DGPS:" before the RTCM message apparently confuses Garmin GPS receivers and they will not recognize the RTCM information that follows. The PacComm PicoPacket TNC has a command ADRDISP OFF which turns off the address information. Data from the PicoPacket now looks like:

```
Y~A@GX|jBCa|_hNOUD...
```

And Garmin GPS receivers will accept this.

## In Case of Problems

### First Time On

When the Oncore receiver powers up for the first time after factory shipment, it is configured in the Position Fix mode and Motorola Binary format. By default, the initial data and time will be incorrect. It will take approximately 15 minutes for the Oncore to collect new Almanac data. If the Oncore has a backup battery, the next time it is powered up the data will be current for the location and acquiring a fix will occur much sooner. The TAC32 program will initialize the Oncore for you upon program startup. If you use the Motorola PC Controller Utility software, you must manually enter the initialization commands. Instructions for operating PC Controller Utility is in the Oncore Quick Start Guide (Part No. 68P41118U01), available from Motorola

### Initializing the Motorola Oncore VP

The Oncore VP will not do anything unless commanded. If it appears that nothing is coming from the Oncore, it is possible that it did not get initialized properly. The TAC32 program will initialize the Oncore for you upon program startup. For the Motorola PC Controller Utility program, you must enter the commands manually.

### The Oncore VP won't get a fix

Try loading the Motorola PC Controller Utility program and enter "default." This will reset the Oncore VP. Initialization parameters must be reentered.

### The Oncore is outputting data but the DGPSIB appears to be not working

The microcontroller on DGPSIB has been programmed with a 72 ms power reset parameter enabled. However, if the DGPSIB's power is applied too slow, the microcontroller will hang. Try turning the power off for 3 seconds and turning it back on. If that does not work, ground pin 1 of the microcontroller momentarily. This will reset the microcontroller and it should start working.